



FOUNDATION INVESTIGATION AND DESIGN REPORT
for
RETAINING WALLS
HIGHWAY 403 EBL NEW BRIDGE OVER DESJARDINS CANAL
GWP 2357-09-00
HAMILTON AREA, ONTARIO

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Geocres No.: 30M5-321
January 21, 2016



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FOUNDATION INVESTIGATION REPORT
for
Retaining Walls
Highway 403 EBL New Bridge over Desjardins Canal
GWP 2357-09-00
Hamilton Area, Ontario

1. INTRODUCTION

This report summarises the results of a foundation investigation carried out for construction of retaining walls associated with a replacement of existing eastbound bridge over the Desjardins Canal located on Highway 403 near Hamilton, Ontario. The investigation was conducted for Morrison Hershfield Limited on behalf of the Ministry of Transportation of Ontario (MTO).

Highway 403 passes over the Desjardins Canal at approximate Station 25+586, Highway 403 chainage (ref. General Arrangement Drawing 'Desjardins Canal Bridge EBL Structure Replacement' prepared by Morrison Hershfield Limited in November 2015). It is intended to replace the existing bridge on a new alignment 17 to 19 m east of the existing EBL centreline.

The project involves construction of retaining walls for the new EBL bridge north and south of the Desjardins Canal. The investigation program was developed based on a drawing 'Highway 403 / Desjardins Canal. New Construction' prepared by Morrison Hershfield and showing two retaining walls envisaged to be about 230 m long south of the Desjardins Canal (Sta. 15+330 to 15+560) and 210 m long north of the canal (Sta. 15+615 to 15+825). The south retaining wall was later shortened as a result of optimising the grading at the site. The updated version of the drawing received in November 2015 indicates that six retaining walls are planned as follows:

Table 1 – Retaining Wall Locations

WALL No.	RETAINING WALLS	STATIONS (new chainage)	LENGTH (m)
RW1	Southwest RSS Wall	Sta. 25+535.5 to 25+555.0	19.5
RW2	Northwest RSS Wall	Sta. 25+617.4 to 25+627.2	9.8
RW3	Southeast RSS Wall	Sta. 25+527.5 to 25+556.0	28.5
RW4	Northeast RSS Wall	Sta. 25+616.4 to 25+629.9	13.5
RW5	Soldier Pile Wall	Sta. 25+629.9 to 25+725.4	95.5
RW6	Toe Wall	Sta. 25+725.4 to 25+821.9	96.5



The existing road grade on Highway 403 at the bridge location is at approximate elevation 86.0. The existing approach embankments are about 8 m high. The water level in the canal is at elevation 75.0.

The report provides subsurface information pertaining to the proposed retaining walls.

All elevations in this report are expressed in meters.

2. SITE DESCRIPTION AND GEOLOGY

The structure to be replaced carries Highway 403 eastbound traffic over the Desjardins Canal connecting Hamilton Harbour and Lake Cootes Paradise near Hamilton. At the location of the bridge, Highway 403 runs approximately in the south-north direction.

The proposed retaining walls will support new high fill / deep cut sections. South of the Desjardins Canal, there is an adjacent railway embankment to the east of the new EBL embankment. The retaining walls to the north of the canal will be erected for up to 7 m high fill / 4.5 m deep cut between the new EBL embankment and York Boulevard, with an approximately 40 m long cut sloping up to 19 m high banks at York Boulevard.

The Desjardins Canal is about 30 m wide and 3 m deep. A pedestrian trail running under the bridge along its south abutment is at approximate elevation 77.5.

The project site is located just west of Lake Ontario. The land surface adjacent to the canal is flat to gently undulating.

The site forms part of the Lake Iroquois offshore deposits consisting mainly of fine grained sands becoming silty with depth and resting on early Lake Iroquois clays. The deposits are generally stratified.

Bedrock in the vicinity of the site is at depths exceeding 35 m.



3. INVESTIGATION PROCEDURES

The field work for this study was carried out during the period of April 29 to August 29, 2015 and comprised nine boreholes advanced to depths of 3.5 to 31.5 m. The borehole locations are indicated on Drawing RW-1, attached. Boreholes EB-2 to EB-5 drilled for the design and construction of the new EBL bridge were also used for the retaining walls.

The locations of the boreholes were established in the field by Peto MacCallum Ltd. The coordinates and ground surface elevations at the boreholes were provided by Callon-Dietz Inc.

The boreholes were advanced using continuous flight hollow and solid stem augers, powered by track- and truck-mounted drill rigs, supplied and operated by specialist drilling contractors, working under the full-time supervision of a member of our engineering staff. A mud rotary technique was used to extend one borehole.

Representative soil samples were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests (SPT) were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

Groundwater conditions at the borehole locations were assessed during drilling by visual examination of soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open boreholes. A piezometer was installed in borehole RW-8, with three sets of readings taken. The boreholes were backfilled with bentonite/cement grout where required in accordance with the MTO guidelines and MOE Regulation 903 for borehole abandonment procedures.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. Recovered soil samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determination. Atterberg limits testing (1) and grain size distribution analyses (17) were conducted on selected soil samples. The laboratory test results are presented in Figures RW-GS-1 to RW-GS-5, RW-PC-1 and on the corresponding logs.



4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard penetration test data and groundwater observations. The results of laboratory Atterberg limits testing, grain size distribution analyses and natural moisture content determinations are also shown on the Record of Borehole sheets.

The borehole locations and stratigraphic profile prepared from the borehole data are shown on Drawing RW-1. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised topsoil over fill overlying sandy soils underlain by discontinuous clayey silt and sandy silt / silt. Cobbles and probable boulders were encountered in five boreholes. The groundwater was at elevation 74.9 to 75.3. The water level in the Desjardins Canal was at elevation 75.0 on August 30, 2015.

The strata encountered are summarised below.

4.1 Topsoil

Surficial topsoil was present in boreholes RW-2 to RW-5, RW-7, EB-2, EB-3 and EB-5. The silty topsoil was 150 to 300 mm thick and penetrated at elevation 82.8 to 87.2.

4.2 Fill

Granular fill consisting of sand and gravel was present surficially in boreholes RW-6, RW-8 and RW-9. The granular fill was covered by asphalt in borehole RW-8 put down on the shoulder of York Boulevard. The sand and gravel fill was loose to dense (SPT-'N' values of 8 to 48), 5 to 13% in moisture content and extended to depths of 1.4 to 1.8 m (elevation 85.3 to 102.8). It is noteworthy that cobbles were encountered in the granular fill in boreholes RW-6 and RW-8.



Sand / silty sand fill was present surficially in boreholes RW-1, EB-4 and below the topsoil or sand and gravel fill at depths of 0.2 to 1.4 m (elevation 82.8 to 87.2) in boreholes RW-2, RW-3, RW-5, RW-7, RW-9 and EB-2. The fill was very loose to dense (SPT-'N' values of 2 to 42) and had a moisture content ranging from 3 to 15%. The sand / silty sand fill was penetrated at depths of 0.6 to 5.2 m (elevation 79.5 to 86.4).

The results of grain size distribution analyses performed on 2 samples of the sand fill are presented in Figure RW-GS-1.

4.3 Sandy Soils

Overlain by the topsoil or fill at depths of 0.3 to 5.2 m (elevation 79.5 to 102.8) in all the boreholes were sandy soils of various granulometric composition (sand, silty sand, sand and silt, gravelly sand). This stratum was very loose to compact becoming dense to very dense, with a moisture content of 3 to 24%. Containing seams of clayey silt / silty clay, the sandy soils had a thickness of 3.0 to 26.3 m in boreholes RW-8, RW-9, EB-2 to EB-5 and were penetrated at depths of 7.3 to 28.1 m (elevation 60.1 to 79.4). The remaining boreholes were terminated in the stratum at depths of 3.5 to 6.7 m (elevation 78.4 to 84.0). It is worth noting that the sandy soils contained cobbles in boreholes RW-8 and EB-3.

The results of grain size distribution analyses conducted on 13 samples of the stratum are presented in Figures RW-GS-2 and RW-GS-3.

4.4 Sandy Silt / Silt

Underlying the sandy soils or clayey silt at depths of 7.3 to 30.0 m (elevation 60.1 to 79.4) in boreholes RW-8, RW-9, EB-2 to EB-5 was sandy silt / silt. This unit was compact to very dense (SPT-'N' values of 26 to over 103) and had a moisture content of 5 to 24%. The sandy silt / silt was not penetrated upon termination of drilling at depths of 9.6 to 31.5 m (elevation 53.8 to 77.1).



The results of grain size distribution analysis performed on a sample of the silt are presented in Figure RW-GS-4.

4.5 Clayey Silt

A layer of clayey silt was revealed below the sand at a depth of 28.1 m (elevation 76.5) in borehole RW-8. This layer was 1.9 m in thickness and hard in consistency as assessed by an SPT-'N' value of 51. The clayey silt was penetrated at 30.0 m depth (elevation 74.6).

The results of Atterberg limits testing and grain size distribution analysis conducted on the cohesive sample from borehole 101 are presented in respective Figures RW-PC-1 and RW-GS-5. The liquid and plastic limits of the clayey silt were 28 and 15 respectively, thus giving the plasticity index of 13.

4.6 Groundwater

In the process of augering, water was detected at depths of 3.0 to 10.2 m (elevation 74.5 to 80.0) in boreholes RW-2, RW-9, EB-2 to EB-5 and at 14.5 m depth (elevation 90.1) in borehole RW-8 put down on York Boulevard. No groundwater was present in boreholes RW-1 to RW-9 upon completion of drilling.

Two piezometers were installed in boreholes EB-3 and EB-4. Three sets of piezometer readings subsequently taken showed water levels to be at the following depths / elevations:

Table 4.6.1 – Groundwater Readings in Piezometers in Boreholes EB-3 and EB-4

Borehole No.	June 10, 2015		July 9, 2015		August 30, 2015	
	Depth, m	Elevation	Depth, m	Elevation	Depth, m	Elevation
EB-3	10.4	74.9	10.1	75.2	10.2	75.1
EB-4	–	–	10.1	75.3	10.3	75.1



A piezometer with a tip at elevation 87.2 was also installed in borehole RW-8. Three sets of piezometer readings showed water levels to be at the following depths / elevations:

Table 4.6.2 – Groundwater Readings in Piezometer in Borehole RW-8

Borehole No.	September 4, 2015		September 7, 2015		November 26, 2015	
	Depth, m	Elevation	Depth, m	Elevation	Depth, m	Elevation
RW-8	17.2	87.4	17.1	87.5	>17.2 (Dry)	<87.4

The water level in the Desjardins Canal was at elevation 75.0 on August 30, 2015. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns, generally reflecting the water level in the adjacent Desjardins Canal.



5. CLOSURE

The field work was carried out under the supervision of Mr. F. Portela, Senior Technician, under the coordination of Mr. K. Daly, B.Eng, and direction of Mr. C.M.P. Nascimento, P.Eng., Project Manager. The equipment was supplied by Elite Drilling Services and Altech Drilling & Investigative Services Ltd.

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Project Manager and MTO Designated Principal Contact.

Yours very truly,

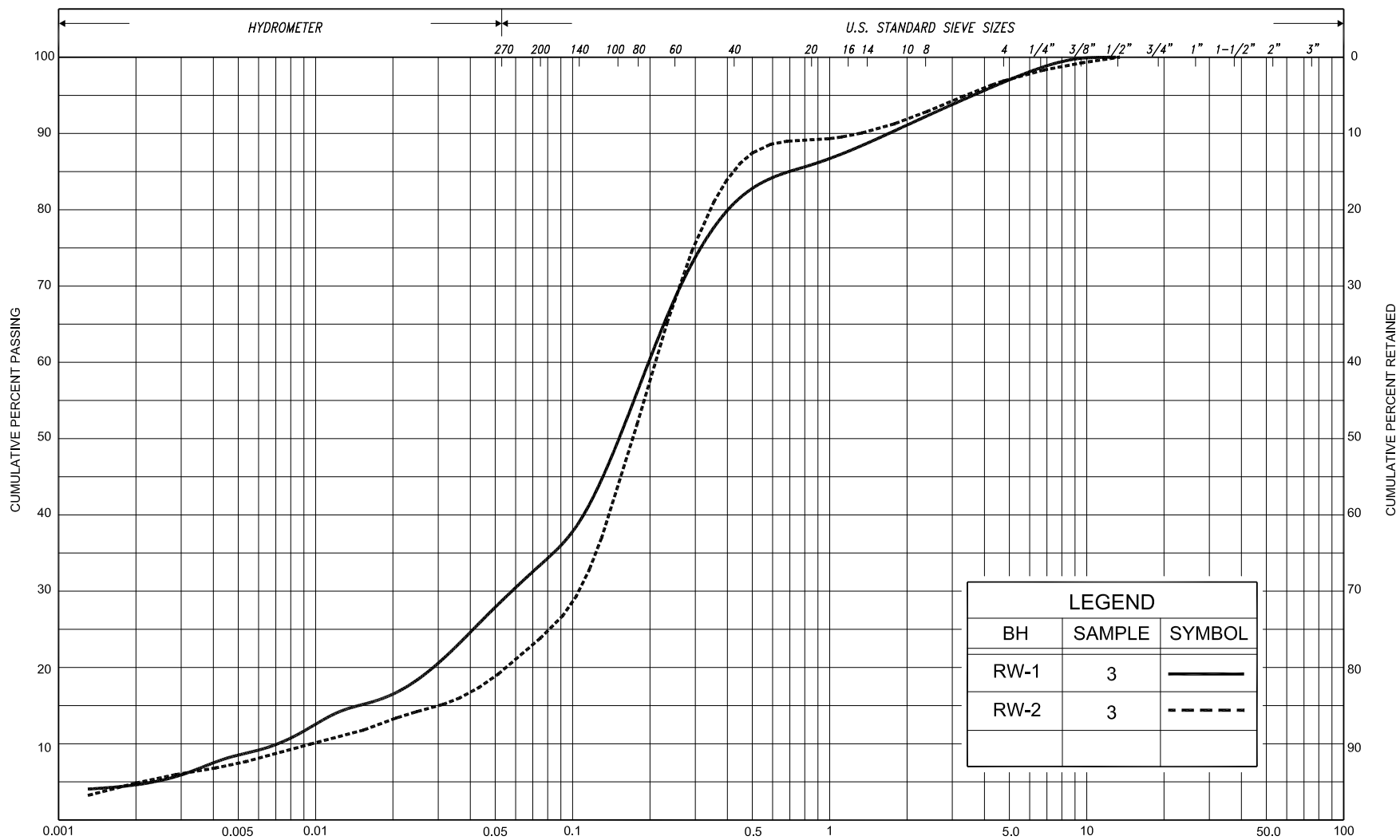
Peto MacCallum Ltd.



Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact



SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED		
					SAND								M.I.T.			
CLAY	FINE		MEDIUM		COARSE	FINE		MEDIUM		COARSE		GRAVEL			COBBLES	
	SILT							SAND								
CLAY			SILT			V. FINE	FINE	MED.	COARSE	GRAVEL					U.S. BUREAU	
					SAND											

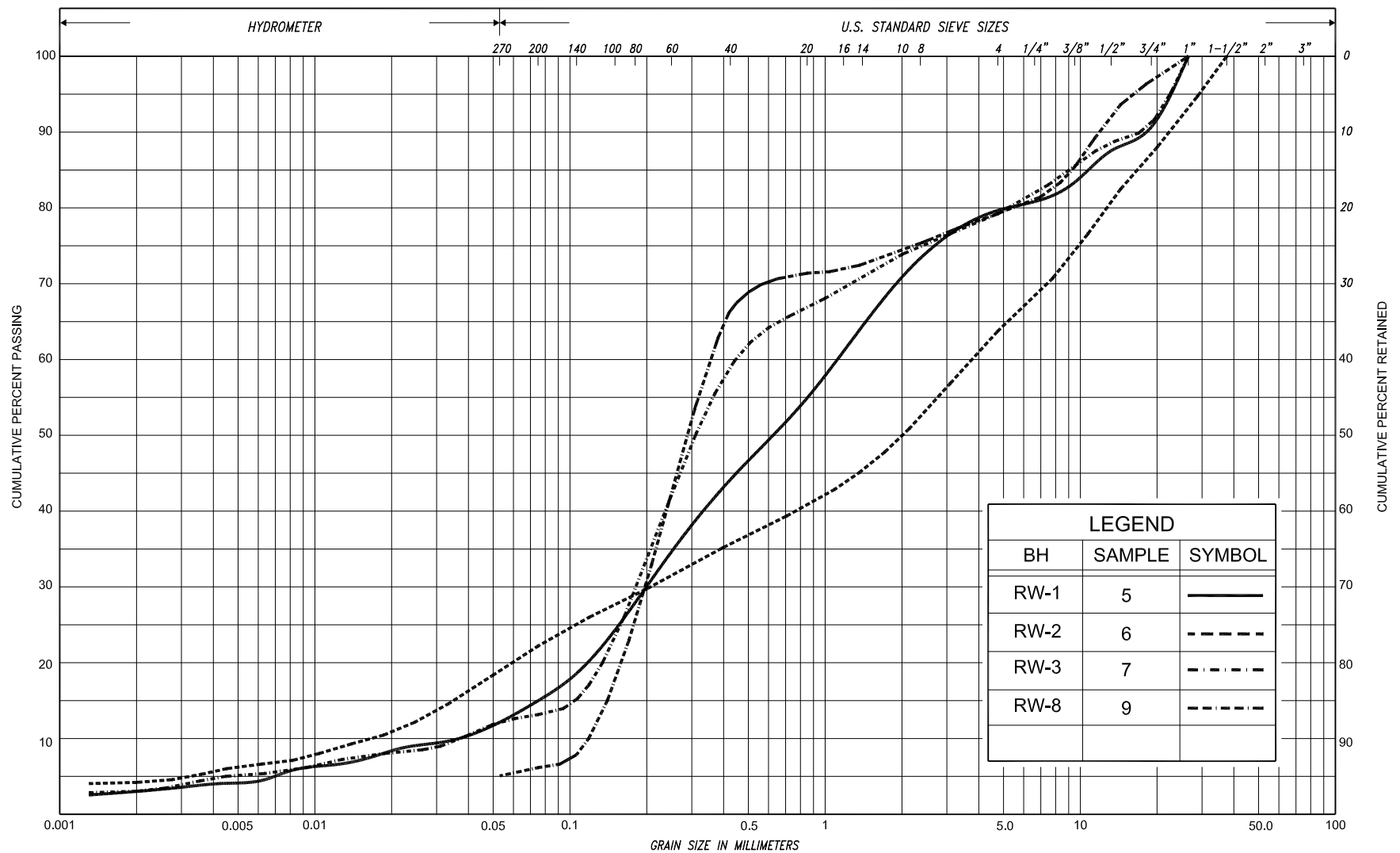


GRAIN SIZE DISTRIBUTION SAND, some to with silt, trace clay, trace gravel (FILL)

FIG No. RW-GS-1

HWY: 403

W.P. No. 2357-09-01



SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COB BLES	UNIFIED	
				SAND									
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL				COBBLES	M.I.T.	
			SILT										
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL				U.S. BUREAU	
				SAND									



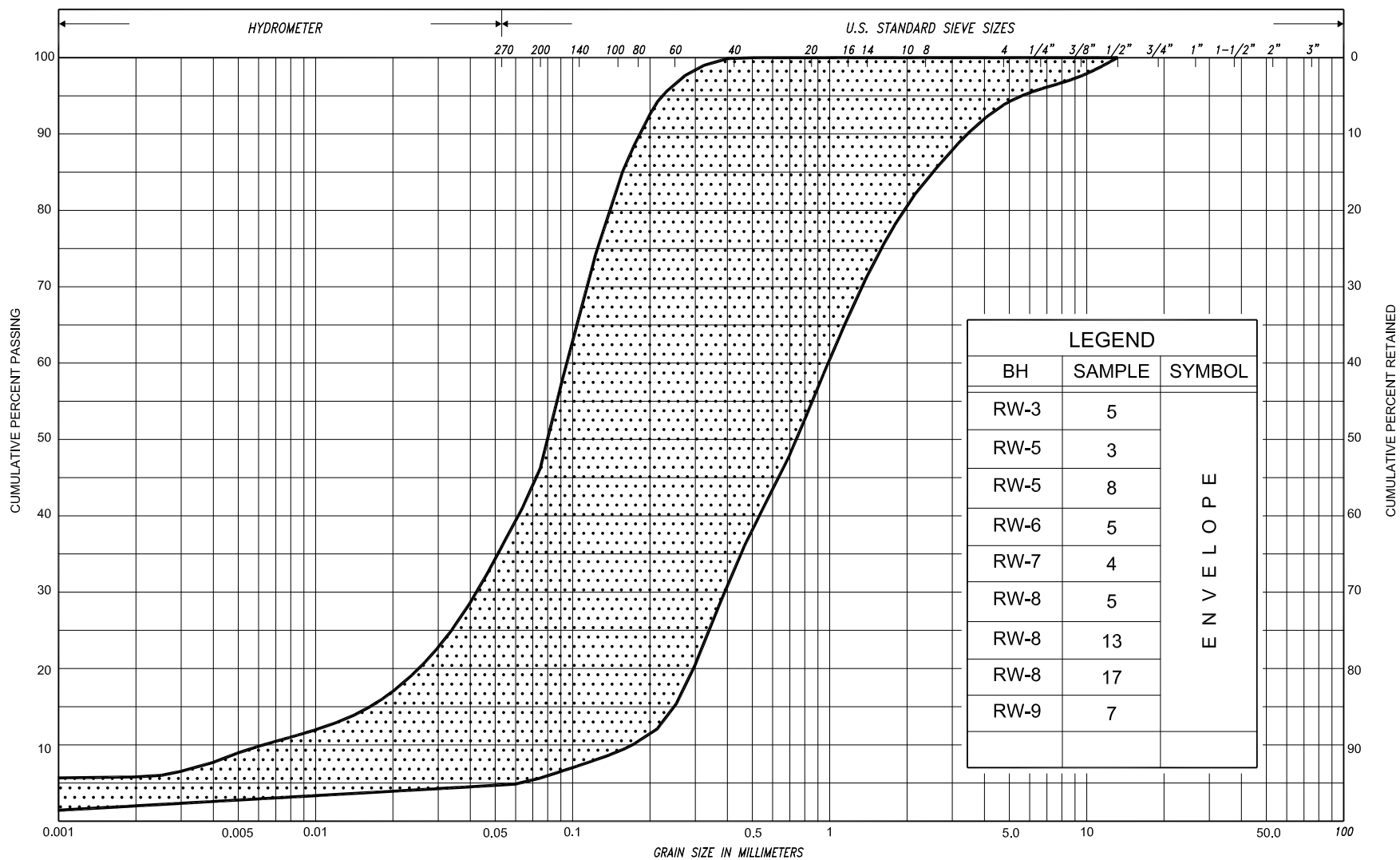
GRAIN SIZE DISTRIBUTION

SAND, some gravel to gravelly, trace to some silt, trace clay

FIG No. RW-GS-2

HWY: 403

W.P. No. 2357-09-01



SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COB BLES	UNIFIED	
				SAND									
CLAY	FINE		MEDIUM	COARSE	FINE	MEDIUM		COARSE	GRAVEL		COBBLES	M.I.T.	
	SILT				SAND								
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL				U.S. BUREAU
				SAND									



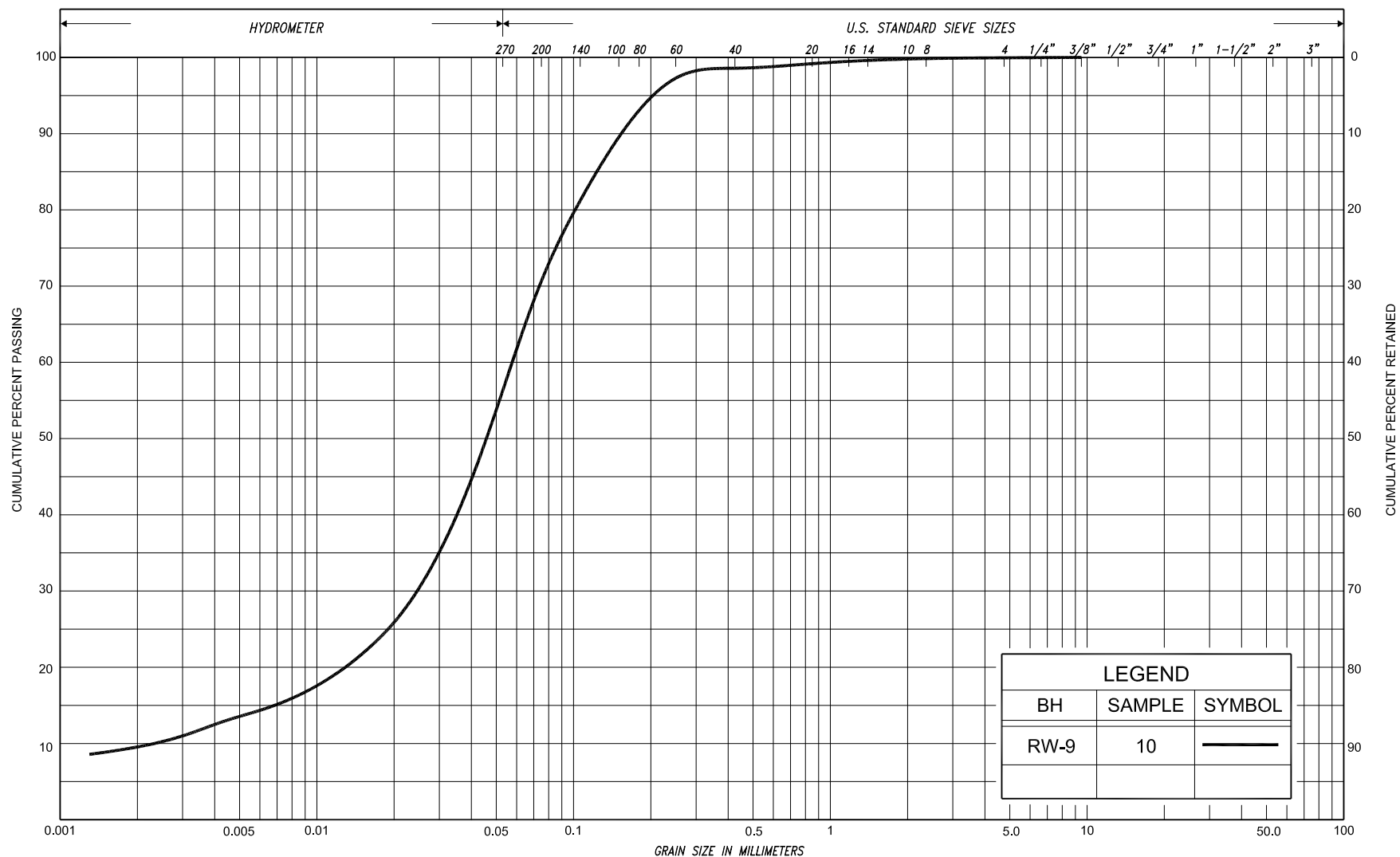
GRAIN SIZE DISTRIBUTION

SAND, trace silt to silty, trace clay, trace gravel

FIG No. RW-GS-3

HWY: 403

W.P. No. 2357-09-01



SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COB BLES	UNIFIED	
				SAND										
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.	
	SILT													
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL						U.S. BUREAU
				SAND										



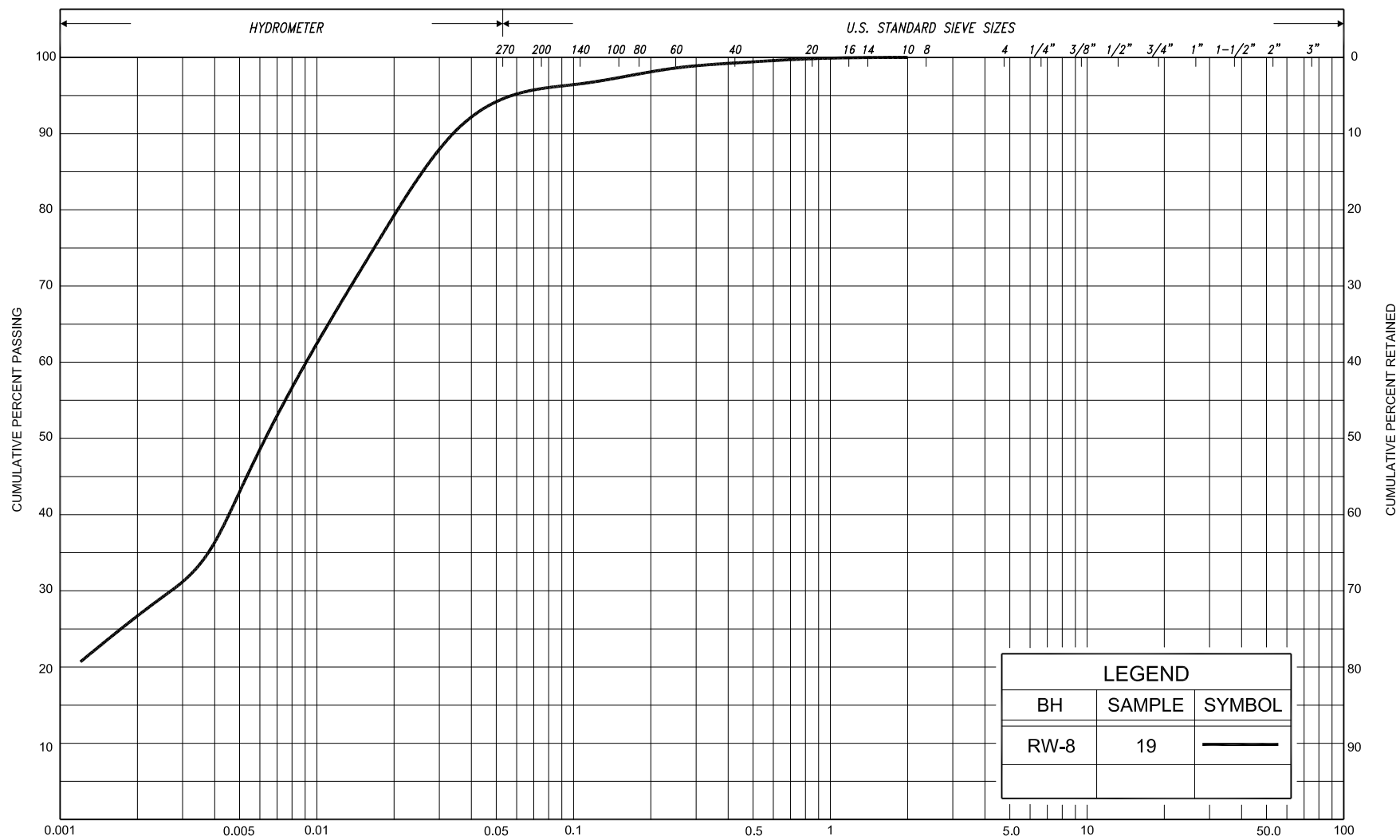
GRAIN SIZE DISTRIBUTION

SILT, with sand, trace clay

FIG No. RW-GS-4

HWY: 403

W.P. No. 2357-09-01



SILT & CLAY				FINE	MEDIUM	COARSE	GRAVEL		COBBLES	UNIFIED
				SAND						
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL		COBBLES	M.I.T.
				SAND						
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL		U.S. BUREAU
				SAND						

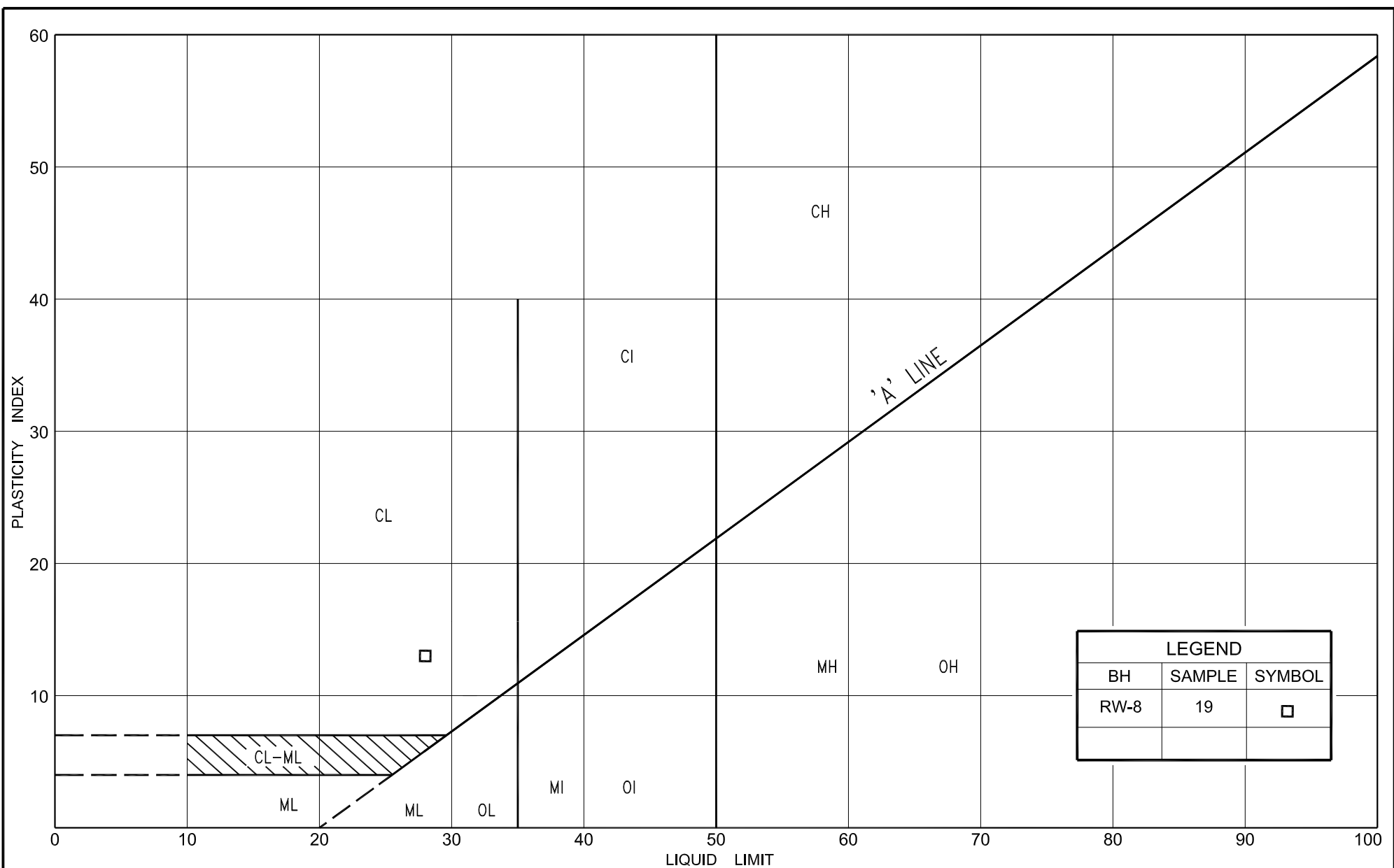


GRAIN SIZE DISTRIBUTION CLAYEY SILT, trace sand (CL)

FIG No. RW-GS-5

HWY: 403

W.P. No. 2357-09-01



LEGEND		
BH	SAMPLE	SYMBOL
RW-8	19	□



PLASTICITY CHART
CLAYEY SILT, trace sand (CL)

FIG No.	RW-PC-1
HWY:	403
W.P. No.	2357-09-01

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm* IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL











ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	e_{max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m ³	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
γ_w	kN/m ³	UNIT WEIGHT OF WATER	w_L	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_p	%	PLASTIC LIMIT	D_n	mm	n PERCENT - DIAMETER
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_s	%	SHRINKAGE LIMIT	C_u	1	UNIFORMITY COEFFICIENT
ρ_d	kg/m ³	DENSITY OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	m ³ /s	RATE OF DISCHARGE
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL	WTP		WETTER THAN PLASTIC LIMIT	j	kN/m ³	SEEPAGE FORCE
e	1, %	VOID RATIO						

RECORD OF BOREHOLE No RW-1

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 156.9 N ; 272 964.3 E **ORIGINATED BY** S.A.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** April 29, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
83.0	Ground Surface							20	40	60	80	100								
0.0	Sand, with silt trace clay, trace gravel organic inclusions Loose to Brown Moist very loose (FILL)		1	SS	5									○						
							82							○						
			2	SS	2															
														○						
			3	SS	3		81										3 63 29 5			
80.9	Sand, some gravel some silt, trace clay Loose Brown Moist													○						
2.1			4	SS	5		80							○						
																				
			5	SS	9									○			20 65 12 3			
79.3	End of borehole																			
3.7																				
	* Borehole dry																			

RECORD OF BOREHOLE No RW-2

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 192.0 N ; 272 973.1 E **ORIGINATED BY** S.A.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** April 29, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					w _p w w _L					
83.0	Ground Surface							20	40	60	80	100						
0.0	Topsoil _____ Silty sand _____ topsoil inclusions _____		1	SS	6	▽*	82							○			3 73 19 5	
	Loose Brown Moist														○			
	Sand, some silt _____ trace clay, trace gravel _____		2	SS	6										○			
	Loose Reddish Moist brown		3	SS	6										○			
	(FILL) _____ organics _____		4	SS	4										○			
80.0	Dark brown								80							○		
3.0	Sand, some gravel some silt, trace clay		5	SS	9	▽*	79							○			36 42 18 4	
	Loose Brown Wet														○			
	gravelly		6	SS	8									○				
78.6	End of borehole																	
4.4																		
										</								

* 2015 04 29

▽ Water level observed
during drilling

RECORD OF BOREHOLE No RW-3

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 265.5 N ; 272 994.3 E **ORIGINATED BY** S.A.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** April 29, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
86.0	Ground Surface						20	40	60	80	100						
0.0	Topsoil Sand, trace silt topsoil pockets		1	SS	3												
	Very loose Reddish Moist to loose brown																
84.8	(FILL)		2	SS	4												
1.2	Sand, trace silt clayey silt seams to 2.1m																
	Loose to Reddish Moist very loose brown		3	SS	4												
			4	SS	3												
	some silt, trace clay trace gravel																
			5	SS	3												
	some to with gravel																
			6	SS	6												
			7	SS	10												
80.8	Compact																
5.2	End of borehole																

RECORD OF BOREHOLE No RW-4

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 303.2 N ; 273 002.1 E **ORIGINATED BY** S.A.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** April 29, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)												
86.1	Ground Surface						20	40	60	80	100						
0.0	Topsoil	△	1	SS	8		86										
0.3	Sand, trace silt	•															
	Loose Reddish Moist brown	•															
	sandy silt layers	•	2	SS	7		85										
	Very loose Brown Wet to to loose moist	•															
		•	3	SS	4		84										
		•															
		•	4	SS	3		83										
		•															
		•	5	SS	5		82										
		•															
		•	6	SS	5		81										
		•															
		•	7	SS	5		80										
		•															
		•	8	SS	9												
79.4	End of borehole																
6.7																	
	* Borehole dry																

RECORD OF BOREHOLE No RW-5

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 423.7 N ; 272 996.9 E **ORIGINATED BY** F.P.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** G.D.
DATUM Geodetic **DATE** July 02, 2015 **CHECKED BY** G.D.


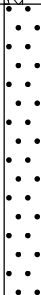
SOIL PROFILE			SAMPLES			GROUND WATER * CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
85.0	Ground Surface						20	40	60	80	100									
0.0	Topsoil		1	SS	18															
84.4	Sand, some silt																			
0.6	Compact Brown Moist (FILL)		2	SS	9															
	Sand some silt, trace clay																			
	Loose to Brown Moist very dense		3	SS	14											0 80 16 4				
			4	SS	23															
			5	SS	25															
			6	SS	27															
			7	SS	31															
			8	SS	52											0 77 19 4				
			9	SS	34															
78.4	End of borehole																			
6.6																				
	* Borehole dry																			

RECORD OF BOREHOLE No RW-6

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 425.9 N ; 272 990.0 E **ORIGINATED BY** F.P.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** G.D.
DATUM Geodetic **DATE** June 22, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
87.4 0.0	Ground Surface Sand and gravel, cobbles Compact Brown Moist (FILL)		1	SS	17		87													
			2	SS	15										○					
86.0 1.4	Sand, some silt to silty trace clay, trace gravel Compact Brown Moist to dense		3	SS	39		86									○				
			4	SS	25		85									○				
			5	SS	32		84									○				
			6	SS	42										○					
83.1 4.3	End of borehole 																			

RECORD OF BOREHOLE No RW-7

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 535.5 N ; 272 989.6 E **ORIGINATED BY** F.P.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** G.D.
DATUM Geodetic **DATE** June 19, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
87.5	Ground Surface							20	40	60	80	100					
0.0	Topsoil		1	SS	21												
87.2	Sand, trace gravel																
0.3	Compact Brown Moist to wet		2	SS	23												
86.4	(FILL)																
1.1	Sand some silt, trace clay		3	SS	19												
	Compact Reddish Wet to moist																
			4	SS	18												
			5	SS	48												
84.0	End of borehole																
3.5																	
	* Borehole dry																

RECORD OF BOREHOLE No RW-8

1 of 3

METRIC

G.W.P. 2357-09-00 LOCATION Coords: 4 793 451.3 N ; 273 042.7 E ORIGINATED BY F.P.
DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.
DATUM Geodetic DATE August 29, 2015 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa										WATER CONTENT (%)		
							20 40 60 80 100										20 40 60		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
104.6	Ground Surface																		
0.0	Asphalt over sand and gravel		1	SS	48														
	Dense Brown Moist																		
	(PAVEMENT FILL)		2	SS	36														
102.8	cobbles																		
			3	SS	24/10cm														
1.8	Sand trace to with gravel trace silt cobbles																		
	Compact to Brown Moist very dense		4	SS	10														
			5	SS	56														
			6	SS	50/8cm														
	cobbles																		
	(Probable fill to El. 90.0)		7	SS	66														
			8	SS	50/10cm														
			9	SS	78														
			10	AS	50/8cm														
			11	SS	50/15cm														
		12	AS	50/15cm															
		13	SS	50/15cm															
	with silt to silty																		
	Wet Cont'd																		

RECORD OF BOREHOLE No RW-8

2 of 3

METRIC

G.W.P. 2357-09-00 LOCATION Coords: 4 793 451.3 N ; 273 042.7 E ORIGINATED BY F.P.
DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.
DATUM Geodetic DATE August 29, 2015 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa												WATER CONTENT (%)		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE														
89.6							20	40	60	80	100	20	40	60							
Sand with to trace silt Dense Brown Wet (Cont'd.) silt layers Compact to Moist very dense			14	SS	33																
			15	SS	27																
				16	SS	39															
			17	SS	79																

RECORD OF BOREHOLE No RW-8

3 of 3

METRIC

G.W.P. 2357-09-00 LOCATION Coords: 4 793 451.3 N ; 273 042.7 E ORIGINATED BY F.P.
DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.
DATUM Geodetic DATE August 29, 2015 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)																						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)																					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE																															
74.6							20	40	60	80	100																												
30.0	Silt, trace to some clay Very dense Brown Wet																																						
73.1			20	SS	56																																		
31.5	End of borehole																																						
<div>* 2015 08 29</div> <div>▽ Water level observed during drilling</div> <div>Monitoring Well Readings:</div> <table><tr><td>Date</td><td>Depth</td><td>Elev.</td></tr><tr><td></td><td>(m)</td><td></td></tr><tr><td>09/04/'15</td><td>17.2</td><td>87.4</td></tr><tr><td>09/07/'15</td><td>17.1</td><td>87.5</td></tr><tr><td>11/12/'15</td><td>Dry</td><td>----</td></tr></table> <div>Monitoring Well Legend:</div> <table><tr><td></td><td>Flush mount cover + concrete</td></tr><tr><td></td><td>Bentonite seal</td></tr><tr><td></td><td>Filter sand</td></tr><tr><td></td><td>50mm dia. PVC screen</td></tr></table>																	Date	Depth	Elev.		(m)		09/04/'15	17.2	87.4	09/07/'15	17.1	87.5	11/12/'15	Dry	----		Flush mount cover + concrete		Bentonite seal		Filter sand		50mm dia. PVC screen
Date	Depth	Elev.																																					
	(m)																																						
09/04/'15	17.2	87.4																																					
09/07/'15	17.1	87.5																																					
11/12/'15	Dry	----																																					
	Flush mount cover + concrete																																						
	Bentonite seal																																						
	Filter sand																																						
	50mm dia. PVC screen																																						

RECORD OF BOREHOLE No RW-9

1 of 1

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 463.8 N ; 272 994.4 E **ORIGINATED BY** F.P.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** G.D.
DATUM Geodetic **DATE** June 22, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
86.7	Ground Surface						20	40	60	80	100									
0.0	Sand and gravel topsoil inclusions		1	SS	8								○							
	Loose Brown Moist												○							
	Sand, trace gravel		2	SS	9															
	Compact Brown Moist to dense		3	SS	19															
	(FILL)		4	SS	42															
			5	SS	35								○							
		6	SS	38								○								
82.4																				
4.3	Sand, some silt trace clay, trace gravel						▽*											1 81 12 6		
	Dense to Brown Moist compact		7	SS	36									○						
			8	SS	29									○						
			9	SS	28								○							
79.4																				
7.3	Silt with sand, trace clay																0 29 62 9			
	Very dense Brown Moist		10	SS	52								○							
	Dense Wet																			
77.1																				
9.6	End of borehole																			

RECORD OF BOREHOLE No EB-1

1 of 1

METRIC

G.W.P.	2357-09-01	LOCATION	Coords: 4 793 308.3 N ; 272 992.1 E	ORIGINATED BY	S.A.
DIST	Niagara	HWY	403	BOREHOLE TYPE	Continuous Flight Solid Stem Augers
DATUM	Geodetic	DATE	April 28, 2015	CHECKED BY	G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa					W _p	W	W _L		
							20 40 60 80 100									
84.9 0.0	Ground Surface															
	Topsoil sand and gravel pockets (FILL)		1	SS	7											
84.1 0.8	Sand, some to with silt trace clay, trace gravel															
	Loose Brown/ reddish brown Moist		2	SS	5											
			3	SS	4											
			4	SS	5											
	silt seams		5	SS	8											
	sand seams		6	SS	7											
			7	SS	4											
	sandy silt lenses															
			8	SS	8											
	Compact to very dense		9	SS	29											
			10	SS	30											
											</					

RECORD OF BOREHOLE No EB-2

1 of 3

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 333.9 N ; 272 988.2 E **ORIGINATED BY** F.P.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** C.F.H.S.A. + Mud Rotary and Dynamic Cone Penetration Test **COMPILED BY** G.D.
DATUM Geodetic **DATE** June 12, 15 and 16, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa										
							○ UNCONFINED + FIELD VANE										
							● QUICK TRIAXIAL × LAB VANE										
							WATER CONTENT (%)										
							20 40 60 80 100					20 40 60					
84.7	Ground Surface																
0.0	Topsoil		1	SS	6												
	Sand, trace silt topsoil inclusions to 0.8m																
	Loose to Brown Moist compact		2	SS	7												
			3	SS	12												
	trace gravel																
			4	SS	4												
	(FILL)																
			5	SS	9												
			6	SS	7												
			7	SS	19												
79.5																	
5.2	Sand		8	SS	7												
	some to with silt trace to some clay																
	Loose to Brown Moist compact		9	SS	9												
			10	SS	1												
			11	SS	23												
	trace gravel																
	Dense to Wet very dense		12	SS	41												
			13	SS	80												
			14	SS	34												
69.7																	

RECORD OF BOREHOLE No EB-2

2 of 3

METRIC

G.W.P. 2357-09-00	LOCATION	Coords: 4 793 333.9 N ; 272 988.2 E	ORIGINATED BY F.P.
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DIST	Niagara	HWY	403	BOREHOLE TYPE	C.F.H.S.A. + Mud Rotary and Dynamic Cone Penetration Test	COMPILED BY	G.D.
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DATUM Geodetic **DATE** June 12, 15 and 16, 2015 **CHECKED BY** G.D.

[illegible]

RECORD OF BOREHOLE No EB-2

3 of 3

METRIC

G.W.P.	2357-09-00	LOCATION	Coords: 4 793 333.9 N ; 272 988.2 E	ORIGINATED BY	F.P.
DIST	Niagara	HWY	403	BOREHOLE TYPE	C.F.H.S.A. + Mud Rotary and Dynamic Cone Penetration Test
COMPILED BY	G.D.				
DATUM	Geodetic	DATE	June 12, 15 and 16, 2015	CHECKED BY	G.D.

[illegible]

RECORD OF BOREHOLE No EB-3

1 of 3

METRIC

G.W.P. 2357-09-01 LOCATION Coords: 4 793 328.5 N ; 273 002.8 E ORIGINATED BY F.P.
DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.
DATUM Geodetic DATE April 30, May 01 and June 10 to 12, 2015 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa					
85.3	Ground Surface								20 40 60 80 100					
0.0	Topsoil		1	SS	3			85						
85.0	Sand, trace silt topsoil seams to 1.2m													
0.3	Very loose Brown Moist to loose		2	SS	4			84						
	some silt to silty trace clay, trace gravel													
			3	SS	3									
			4	SS	3									
			5	SS	3									
			6	SS	7									
			7	SS	8									
			8	SS	8									
	cobbles to 6.7m													
	Compact to dense		9	SS	15									
			10	SS	35									
			11	SS	30									
	Wet		12	SS	23									
			13	SS	25									
			14	SS	32									
70.3														

RECORD OF BOREHOLE No EB-3

2 of 3

METRIC

G.W.P. 2357-09-01 **LOCATION** Coords: 4 793 328.5 N ; 273 002.8 E **ORIGINATED BY** F.P.
DIST Niagara **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers + Mud Rotary **COMPILED BY** G.D.
DATUM Geodetic **DATE** April 30, May 01 and June 10 to 12, 2015 **CHECKED BY** G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						W _p	W	W _L
70.3							20	40	60	80	100								
15.0	Sand some silt, trace clay Compact to Brown Wet very dense (Cont'd.)		15	SS	28		70												
							69												
			16	SS	33		68												
							67												
			17	SS	36		66												
							65												
	clayey silt layers Moist		18	SS	53		64												
							63												
	with silt Dense Wet						62												
			19	SS	40		61												
							60												
60.7							59												
24.6	Silt some clay, trace sand Compact Grey Moist to dense		20	SS	26		58												
							57												
	some to with sand Very dense Grey Moist		21	SS	81		56												
55.3	Cont'd																		

RECORD OF BOREHOLE No EB-3

3 of 3

METRIC

G.W.P. 2357-09-01 LOCATION Coords: 4 793 328.5 N ; 273 002.8 E ORIGINATED BY F.P.
DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.
DATUM Geodetic DATE April 30, May 01 and June 10 to 12, 2015 CHECKED BY G.D.

SOIL PROFILE					SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)							
						○ UNCONFINED			● QUICK TRIAXIAL	+		×	FIELD VANE					
55.3								20	40	60	80	100						GR SA SI CL
30.0	Silt with sand, trace clay						55											
54.4	Very dense Grey Moist (Cont'd.)		22	SS	57									○				
30.9	End of borehole																	

RECORD OF BOREHOLE No EB-4

1 of 3

METRIC

G.W.P. 2357-09-01 LOCATION Coords: 4 793 410.5 N ; 272 993.4 E ORIGINATED BY F.P.
DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.
DATUM Geodetic DATE July 02 & 03, 2015 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										○		
								● QUICK TRIAXIAL × LAB VANE												
85.4	Ground Surface						20	40	60	80	100									
0.0	Silty sand topsoil and gravel inclusions		1	SS	20								○							
	Compact Reddish Moist brown		2	SS	12								○							
	Sand, trace silt																			
	Loose to Brown Moist compact		3	SS	8								○							
	(FILL)																			
	clayey silt seams		4	SS	17								○							
			5	SS	22								○							
81.4	Sand some silt, trace clay		6	SS	38								○							
4.0	Compact to Brown Moist very dense		7	SS	26								○			0 80 (20)				
			8	SS	30								○							
			9	SS	28								○							
			10	SS	52								○							
			11	SS	38								○			0 78 17 5				
			12	SS	53								○							

Cont'd

RECORD OF BOREHOLE No EB-4

2 of 3

METRIC

G.W.P. 2357-09-01	LOCATION	Coords: 4 793 410.5 N ; 272 993.4 E	ORIGINATED BY F.P.
-------------------	----------	-------------------------------------	--------------------

DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.

DATUM Geodetic DATE July 02 & 03, 2015 CHECKED BY G.D.

[illegible]

RECORD OF BOREHOLE No EB-4

3 of 3

METRIC

G.W.P. 2357-09-01	LOCATION	Coords: 4 793 410.5 N ; 272 993.4 E	ORIGINATED BY F.P.
-------------------	----------	-------------------------------------	--------------------

DIST Niagara HWY 403 BOREHOLE TYPE Continuous Flight Hollow Stem Augers + Mud Rotary COMPILED BY G.D.

DATUM Geodetic DATE July 02 & 03, 2015 CHECKED BY G.D.

[illegible]

RECORD OF BOREHOLE No EB-5

1 of 3

METRIC

G.W.P. 2357-09-01	LOCATION	Coords: 4 793 409.4 N ; 273 008.7 E	ORIGINATED BY F.P.
--------------------------	-----------------	-------------------------------------	---------------------------

DIST Niagara	HWY 403	BOREHOLE TYPE C.F.H.S.A. + Mud Rotary and Dynamic Cone Penetration Test	COMPILED BY G.D.
---------------------	----------------	--	-------------------------

DATUM Geodetic **DATE** June 26, 29 & 30, 2015 **CHECKED BY** G.D.

SOIL PROFILE					SAMPLES			
ELEV DEPTH	DESCRIPTION				STRAT PLOT	NUMBER	TYPE	"N" VALUES
85.8	Ground Surface							
0.0	Topsoil					1	SS	13
85.5	Sand, some silt topsoil inclusions to 1.8m depth							
0.3	Compact Brown Moist					2	SS	15
						3	SS	17
						4	SS	24
						5	SS	19
						6	SS	28
	trace gravel sandy silt seams							
	Dense to very dense					7	SS	35
						8	SS	45
						9	SS	30
						10	SS	50/10cm
	Wet					11	SS	83
	silty clay seams to 11.3m depth							
						12	SS	54
	with silt							
						13	SS	75
						14	SS	44
	Cont'd							

RECORD OF BOREHOLE No EB-5

2 of 3

METRIC

G.W.P. 2357-09-01	LOCATION	Coords: 4 793 409.4 N ; 273 008.7 E	ORIGINATED BY F.P.
-------------------	----------	-------------------------------------	--------------------

DIST Niagara HWY 403 BOREHOLE TYPE C.F.H.S.A. + Mud Rotary and Dynamic Cone Penetration Test COMPILED BY G.D.

DATUM Geodetic DATE June 26, 29 & 30, 2015 CHECKED BY G.D.

[illegible]

RECORD OF BOREHOLE No EB-5

3 of 3

METRIC

G.W.P. 2357-09-00	LOCATION	Coords: 4 793 409.4 N ; 273 008.7 E	ORIGINATED BY F.P.
--------------------------	-----------------	-------------------------------------	---------------------------

DIST	Niagara	HWY	403	BOREHOLE TYPE	C.F.H.S.A. + Mud Rotary and Dynamic Cone Penetration Test	COMPILED BY	G.D.
-------------	---------	------------	-----	----------------------	---	--------------------	------

DATUM Geodetic **DATE** June 26, 29 & 30, 2015 **CHECKED BY** G.D.

[illegible]

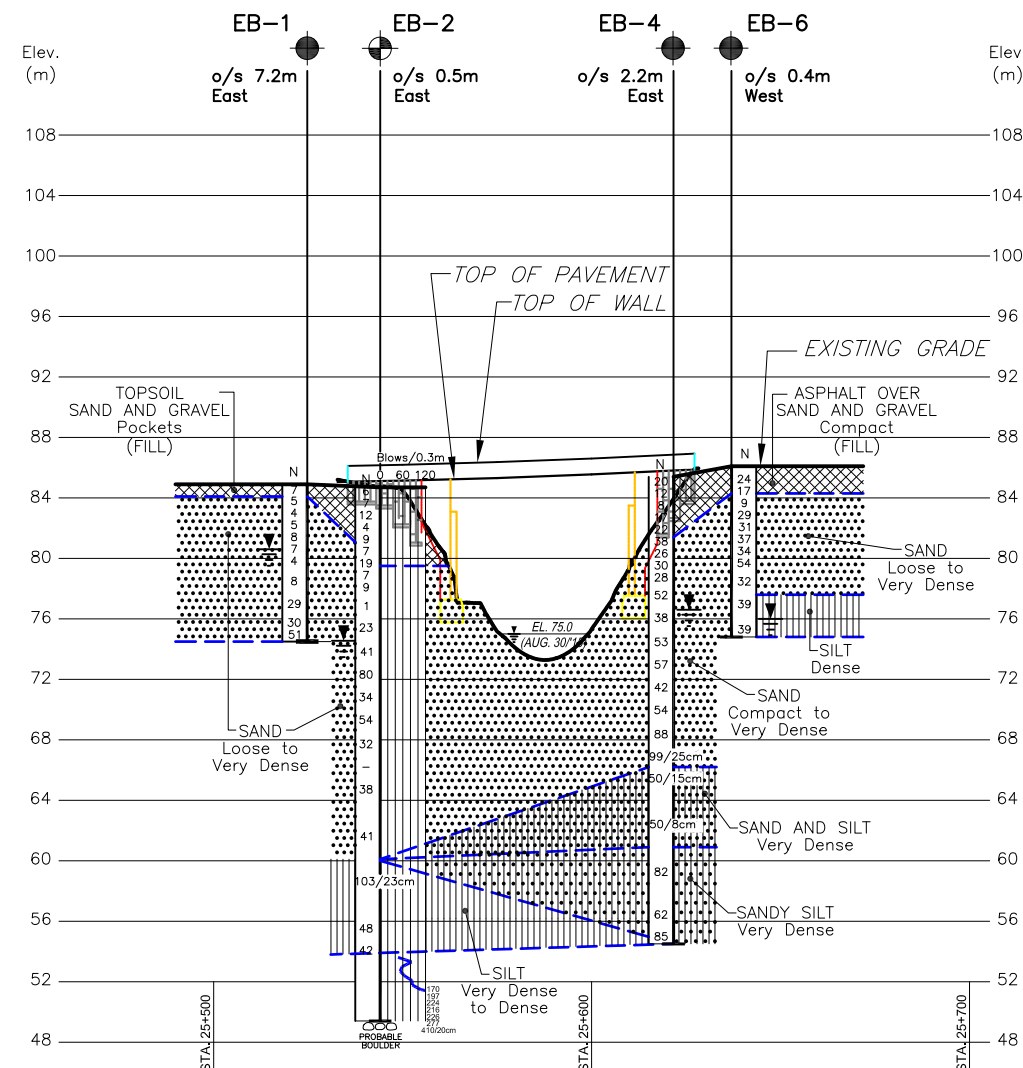
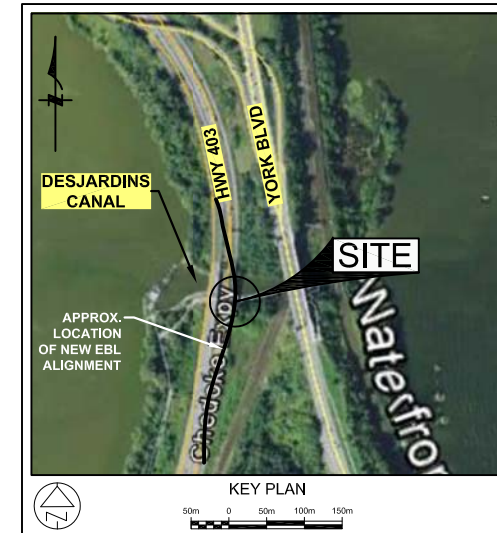
RECORD OF BOREHOLE No EB-6

1 of 1

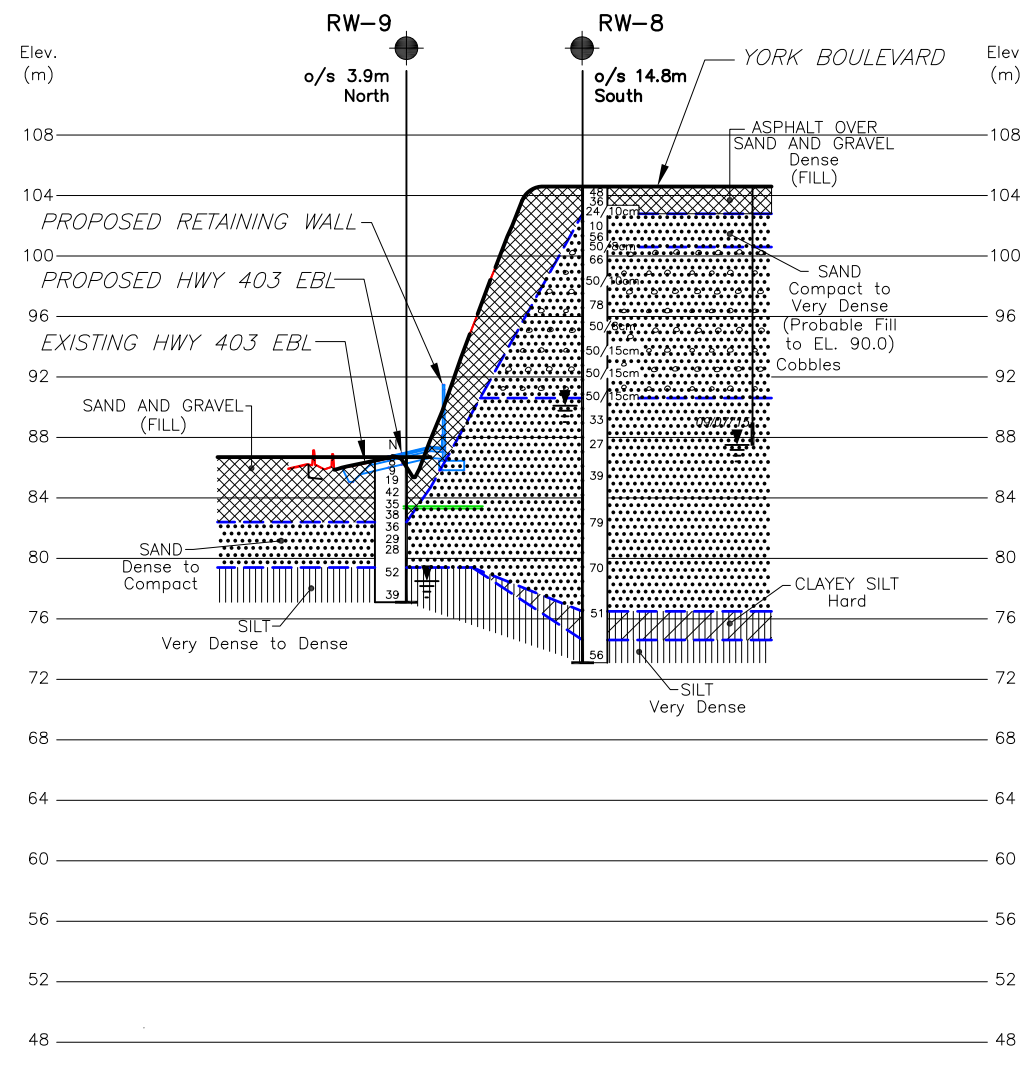
METRIC

G.W.P.	2357-09-01	LOCATION	Coords: 4 793 425.9 N ; 272 990.0 E	ORIGINATED BY	F.P.
DIST	Niagara	HWY	403	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers
DATUM	Geodetic	DATE	July 08 & 09, 2015	COMPILED BY	G.D.
				CHECKED BY	G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT										PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa					WATER CONTENT (%)									
							20 40 60 80 100					20 40 60									
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE														
86.1	Ground Surface					86															
0.0	150mm asphalt over sand and gravel					85															
	Compact Brown Moist		1	SS	24																
	(FILL)																				
84.3			2	SS	17																
1.8	Sand some silt, trace clay					84															
	Loose to Brown Moist very dense		3	SS	9																
			4	SS	29																
			5	SS	31																
			6	SS	37																
			7	SS	34																
			8	SS	54																
	silty clay seams		9	SS	32																
77.6																					
8.5	Silt some sand, some clay		10	SS	39																
	Dense Brown Moist to wet																				
			11	SS	39																
74.8																					
11.3	End of borehole																				
<div>* 2015 07 09</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div>																					



PROFILE B-B



SECTION C-C
(AT STA. 25+675)

LEGEND

- Borehole
- Borehole and Cone
- Dynamic Cone Penetration Test (Cone)
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation April to November 2015
- WH Penetration due to weight of hammer
- * Water level not established
- Head
- ARTESIAN WATER
- Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
FOR DETAILS, REFER TO DWG RW-1			

NOTE

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 30M5-321			
HWY No	403	DIST	Central
SUBM'D	NA	CHECKED	GD
DATE	JAN. 18, 2016	SITE	36-36/1
DRAWN	NA	CHECKED	GD
APPROVED	CN	DWG	RW-2



Reference Morrison Hershfield LTD. Drawings:
ACAD-Desjardins Detail Sections.dwg dated August 25 2015;
x1130336_Hwy 403_Base.dwg and 36-36-RW1

NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- REFER TO DRAWING RW-1 FOR BOREHOLE AND SECTION LOCATIONS.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
- STATIONS ARE IN KILOMETRES AND METRES.



FOUNDATION DESIGN REPORT

for

RETAINING WALLS

HIGHWAY 403 EBL NEW BRIDGE OVER DESJARDINS CANAL

GWP 2357-09-00

CENTRAL REGION, ONTARIO

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Index No.: 114FDR
Geocres No.: 30M5-321
January 21, 2016



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FOUNDATION DESIGN REPORT
for
Retaining Walls
Highway 403 EBL New Bridge over Desjardins Canal
GWP 2357-09-00
Hamilton Area, Ontario

1. INTRODUCTION

1.1 General

This report provides the foundation engineering recommendations regarding design and comments for construction of the proposed retaining walls associated with the replacement of existing eastbound bridge over the Desjardins Canal located on Highway 403 near Hamilton, Ontario. This report was prepared for Morrison Hershfield Limited on behalf of the Ministry of Transportation of Ontario (MTO).

Highway 403 passes over the Desjardins Canal at approximate Station 25+586, Highway 403 chainage (ref. General Arrangement Drawing 'Desjardins Canal Bridge EBL Structure Replacement' prepared by Morrison Hershfield Limited in November 2015). It is intended to replace the existing bridge on a new alignment 17 to 19 m east of the existing EBL centreline.

The project involves construction of six retaining walls to support high fill / deep cut sections along the new EBL embankment to the south and north of the Desjardins Canal. South of the canal, there is an adjacent railway embankment to the east of the new EBL embankment. The retaining walls to the north of the Desjardins Canal will be erected for up to 7 m high fill / 4.5 m deep cut between the new EBL embankment and York Boulevard, with an approximately 40 m long cut sloping up to 19 m high banks at York Boulevard.

Recommendations regarding the geotechnical design and comments for construction of the retaining walls are based on the modified preliminary design plan received in November 2015 and featuring four RSS walls behind the replacement bridge abutments, a soldier pile wall north of the canal and a toe wall farther to the north. The proposed retaining walls have been given the following identification numbers:



Table 1.1 – Retaining Wall Locations

WALL No.	RETAINING WALLS	STATIONS (new chainage)	LENGTH (m)	MAXIMUM HEIGHT (m)
RW1	Southwest RSS Wall	Sta. 25+535.5 to 25+555.0	19.5	4.2
RW2	Northwest RSS Wall	Sta. 25+617.4 to 25+627.2	9.8	4.2
RW3	Southeast RSS Wall	Sta. 25+527.5 to 25+556.0	28.5	5.6
RW4	Northeast RSS Wall	Sta. 25+616.4 to 25+629.9	13.5	6.3
RW5	Soldier Pile Wall	Sta. 25+629.9 to 25+725.4	95.5	5.6
RW6	Toe Wall	Sta. 25+725.4 to 25+821.9	96.5	1.8

All elevations in this report are expressed in metres.

1.2 RSS Walls at the Bridge (RW1 to RW4)

At the locations of the four RSS walls extending to the north and south of the replacement bridge on both sides of the Highway 403 eastbound lanes, boreholes RW-4, EB-2 to EB-5 are considered to be representative for foundation recommendations.

The profiles indicate the RSS walls to be founded about 1.0 to 3.8 m below existing grade at elevation 80.9 to 83.6 for the southwest wall (RW1), at elevation 81.4 to 83.6 for the northwest wall (RW2), at elevation 80.3 to 84.4 for the southeast wall (RW3) and at elevation 80.1 to 83.9 for the northeast wall (RW4).

In summary, the soil stratigraphy at the founding levels of the RSS walls generally comprised very loose to dense sand or cohesionless fill. In the process of augering, water was detected at depths of 8.8 to 10.2 m (elevation 74.5 to 77.0) in boreholes EB-2 to EB-5. The piezometric water level measured in boreholes EB-3 and EB-4 was at depths of 10.1 to 10.4 m (elevation 74.9 to 75.3) during the period of June 10 to August 30, 2015.

It is considered that construction of the four RSS walls is feasible at the site.



1.3 Soldier Pile Wall (RW5)

At the location of the retaining wall to be constructed as a soldier pile and lagging system to the north of the Desjardins Canal, boreholes RW-5, RW-6, RW-9 and EB-5 are considered to be representative for foundation recommendations.

The profile indicates a lower portion of steel HP 310x110 piles to be concreted and founded at elevation 78.5 to 81.7, about 7.0 to 11.5 m below existing grade. The soldier pile wall will be anchored along a middle 45 m long section (Sta. 25+647 to 25+692), with the row of tiebacks at elevation 89.8. Elsewhere, a cantilever soldier pile and lagging system is proposed.

In summary, the soil stratigraphy at the founding level of the soldier pile wall generally comprised compact to very dense, typically dense sand or silt. In the process of augering, water was detected at depths of 8.2 and 8.8 m (elevation 78.5 and 77.0) in boreholes RW-9 and EB-5 respectively. No groundwater was present in the reference boreholes upon completion of drilling.

It is considered that construction of the soldier pile wall is feasible at the site.

1.4 Toe Wall (RW6)

At the location of the toe wall, borehole RW-7 is considered to be representative for foundation recommendations.

This wall may be constructed as a cast-in-place reinforced concrete wall bearing on spread footings. The toe wall is likely to be founded at approximate elevation 86.0, about 1.5 to 2.5 m below existing grade.

In summary, the soil stratigraphy at the founding level of the toe wall comprised compact sand. No groundwater was present in borehole RW-7 during or upon completion of drilling.

It is considered that construction of the toe wall is feasible at the site.



The retaining walls should be designed and analysed for bearing capacity, sliding, overturning and overall stability in accordance with the methods outlined in the Canadian Highway Bridge Design Code (CHBDC) 2006 Edition.

The "red flag" issues outlined in the preceding paragraphs and the recommended methods of overcoming these issues noted in the following sections of the report are intended to alert and aid the designer and the contractor. These comments and recommendations are based on the conditions revealed during the investigation and no responsibility is assumed by the consultants or the MTO for alerting the contractor to all critical issues for each foundation alternative. The requirements to deliver acceptable construction quality remain the responsibility of the contractor.

2. FOUNDATIONS

2.1 General

Retaining wall types such as RSS walls, soldier pile systems and precast or cast-in-place reinforced concrete walls bearing on spread footings are considered to be feasible and are addressed in this report.

Several retaining schemes such as an RSS wall and a soldier pile wall are proposed for the project. A cantilever or anchored soldier pile and lagging system is suitable for the north retaining wall. An RSS wall is the preferred option for the four retaining walls at the bridge.

The foundation frost penetration depth at this site is 1.2 m according to OPSD 3090.101. The seismic site coefficient for the conditions at the site is 1.0 – Type I soil profile as per clause 4.4.6 of the CHBDC – for the anticipated foundation conditions. The zonal acceleration ratio is 0.05. The site is located in Seismic Performance Zone 1.



2.2 RSS Walls

A retained soil system (RSS) could be employed for the four retaining walls at the location of the new EBL bridge. It is envisaged that the RSS walls will be constructed utilising a series of steps in founding level to meet site grading and construction requirements.

We understand that a medium performance and appearance rated RSS wall will be required. The design, supply and construction of the RSS wall should conform to SP 599S22 and SP 599S23.

The founding material of the RSS walls is expected to comprise the native sandy/silty soil or granular engineered fill.

The recommended geotechnical bearing resistance at ultimate limit states (ULS) and serviceability limit states (SLS) for a RSS wall constructed on the native sand / silt is as follows:

Table 2.2.1 – Geotechnical Bearing Resistance for RSS Walls

WALL No.	REFERENCE FOUNDING ELEVATION (m)	REFERENCE BOREHOLES	FOUNDING CONDITIONS	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa) for 25 mm Settlement
RW1	80.9 – 83.6	EB-2	Loose to compact sand fill	225	150
RW2	81.4 – 83.6	EB-4	Loose to dense sand fill / sand	300	200
RW3	80.3 – 84.4	RW-4, EB-3	Very loose to loose sand	150	100
RW4	80.1 – 83.9	EB-5	Compact to dense sand	375	250

The geotechnical parameters employed to design the RSS will be dependent upon the type of backfill required for internal stability of the proprietary system as well as the soil contiguous to the RSS system that will govern global stability, overturning and/or sliding of the base. The following parameters are provided:



Table 2.2.2 – Geotechnical Parameters for RSS walls

PARAMETERS	GRANULAR A / GRANULAR B TYPE II	SAND / SILT
Friction Angle, degrees	35	30
Cohesion, kPa	0	0
Unit Weight, kN/m ³	22.8	20.0

The total estimated settlement of the approach fill near the abutments should be up to 35 mm, which is estimated to be completed within 1 month after fill placement. To minimise the differential settlements, a waiting time of 1 month should be allowed prior to paving.

The horizontal force at the base of the RSS will be resisted in part by the friction force developed through the granular backfill or along the interface between the granular backfill and the founding sandy soil, subject to site specific design details. An unfactored friction factor of 0.6 is considered to be appropriate for both situations at this site. A geotechnical factor of 0.8 should be applied for the computations.

The stability of the retaining walls has been analysed using the geotechnical parameters noted above. The analyses for retaining walls RW3 and RW4 have yielded a factor of safety in excess of 1.5 that is sufficient for the slope to be stable in the long term. The results of the slope stability analyses are presented in Figures 1 and 2, attached.

The RSS supplier should be responsible for specifying the type of backfill material employed, taking into consideration the engineering properties of the proprietary product, the design life of the structure, the pull-out resistance required, drainage requirements and the estimated settlements.

The supplier of the RSS should also be responsible for the detail design of the structure (backfill, reinforcement, internal and external stability) and provide drawings to show pertinent information such as location, length, height, elevations, performance level, appearance, etc.



2.3 Soldier Pile and Lagging System

A soldier pile and lagging system may be considered for the north retaining wall. The profile indicates a lower portion of steel HP 310x110 piles to be concreted and founded at elevation 78.5 to 81.7, about 7.0 to 11.5 m below existing grade. The soldier pile wall will be anchored along a middle 45 m long section (Sta. 25+647 to 25+692), with the row of tiebacks attached to a whaler at elevation 89.8. Elsewhere, a cantilever soldier pile and lagging system is proposed.

The concrete bases of H-piles founded at elevation 78.5 to 81.7 may be designed using a factored geotechnical resistance at ULS of 450 kPa and a geotechnical resistance at SLS of 300 kPa.

Provided the spacing between soldier piles is at least five pile diameters (centre to centre), the unfactored lateral passive resistance developed on the face of the soldier pile below the base of the excavation may be taken as the passive earth pressure developed over a width equivalent to three times the pile diameter and depth of six times the pile diameter. A passive earth pressure coefficient K_p of 3.0 is recommended for this computation.

The following geotechnical parameters should be employed to design the wall:

Table 2.3 – Geotechnical Parameters for Soldier Pile and Lagging System

PARAMETERS	Values
Angle of Internal Friction, degrees	30
Unit Weight, kN/m ³	20.0
Coefficient of Active Earth Pressure K_a	0.33
Coefficient of Earth Pressure At-Rest K_o	0.50
Coefficient of Passive Earth Pressure K_p	3.00



Additional lateral resistance should be provided by installing tiebacks anchored in the compact sandy soils. The unfactored pull-out resistance (R) of anchors grouted in cohesionless material can be estimated using the following equation:

$$R = K_f \sigma'_z L_s A_s$$

where

K_f	=	anchorage coefficient
	=	0.8 for compact sandy soils
σ'_z	=	effective vertical stress at mid-point of anchor
	=	$\gamma' z$
γ	=	effective unit weight of overburden soil
	=	20 kN/m ³ above groundwater level
	=	10.2 kN/m ³ below groundwater level
z	=	depth to mid-point of anchor, m
L_s	=	fixed length of anchor, m
A_s	=	circumference of cross-section of fixed length of anchor, m ² /m

A geotechnical resistance factor of 0.4 should be applied to the computed anchor capacity to determine the ULS resistance.

Stability of the slope at York Boulevard has been analysed at approximate Sta. 25+675. The analysis has yielded a factor of safety of 1.5 that is sufficient for the slope to be stable in the long term. The results of the slope stability analysis are presented in Figure 3, attached.

The ground surface adjacent to the excavation is expected to experience some inward movement and vertical settlement. The magnitude of movements adjacent to a braced cut can be limited by selection of an appropriate lateral earth pressure coefficient provided good quality workmanship and construction practice is employed. The anticipated magnitude of movements is as follows:

	<u>Movement (% of Excavation Depth)</u>
Lateral Movement	
Braced Excavation	0.2
Anchored Wall	0.1
Vertical Movement	0.05



Construction procedures should be specifically suited to limit any consequent settlement of the pavement subgrade behind the excavation face.

Foundations of heavily loaded / settlement sensitive structures and/or utilities, if located within close proximity to the excavation, may require underpinning to preserve the integrity of these structures.

2.4 Cast-in-Place Concrete Walls

Cast-in-place reinforced concrete walls bearing on spread footings are considered to be feasible at the site. The geotechnical resistance values recommended in Table 2.2.1 for the RSS foundations placed on native soils are considered to be appropriate for cast-in-place concrete walls. The varying founding level for the concrete walls should allow for a foundation frost penetration depth of 1.2 m with the exception of toe walls which may be placed at a depth of 0.45 m.

The toe wall proposed between Sta. 25+725.4 and 25+821.9 may be constructed as a cast-in-place concrete wall bearing on spread footings. Borehole RW-7 indicates that the toe wall founded at or below elevation 86.0 may be designed using a factored geotechnical resistance at ULS of 375 kPa and a geotechnical resistance at SLS of 250 kPa.

Additional geotechnical parameters for the design of cast-in-place reinforced concrete walls are included in subsequent paragraphs of this report.

2.5 Structural Fill Pad

Where required due to low geotechnical resistance of the loose to very loose native soils, fill and/or otherwise deleterious materials encountered at the founding levels, the excavation should extend down to compact native soils and be reinstated with structural fill to the subgrade level. The exposed subgrade should be inspected and approved by geotechnical personnel.



The structural fill pad should comprise Granular A material placed in maximum 200 mm thick lifts compacted to 100% of the ASTM D698 (standard Proctor) maximum dry density. The following geotechnical bearing resistance should be used for the design depending on the thickness of a structural fill pad:

Table 2.5.1 – Geotechnical Bearing Resistance for Structural Fill Pad

STRUCTURAL FILL PAD THICKNESS (m)	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Minimum 1.0	225	150
Minimum 2.0	400	250
Minimum 3.0	900	350

The granular fill should extend horizontally a minimum 1.0 m from the edge of the structure to be supported. The granular fill pad should be widening with depth at an inclination of 1 horizontal to 1 vertical (1H:1V).

The following parameters should be used for sliding resistance of retaining wall foundations on a structural fill pad:

Table 2.5.2 – Geotechnical Parameters for Structural Fill Pad

PARAMETER	GRANULAR A
Friction Angle, degrees	35
Cohesion, kPa	0
Unit Weight, kN/m ³	22.8

The structural designer should apply appropriate factors to the values of friction angle and cohesion for the sliding resistance check.

The fill should be placed and compacted in accordance with OPSS.PROV 501. The fill placement should be monitored on a full-time basis by geotechnical personnel to examine and approve materials, to evaluate placement operations and to verify that the specified degree of compaction is achieved uniformly throughout the fill.



3. LATERAL EARTH PRESSURE

The retaining walls and bridge wing walls should be designed to resist the unbalanced lateral earth pressure imposed by the backfill adjacent to the wall. The lateral earth pressure, p (kPa) may be computed using the equivalent fluid pressure diagrams presented in Section 6.9 of the CHBDC or employing the following equation, assuming a triangular pressure distribution:

$$p = K(\gamma h + q) + C_p + C_s$$

where K = coefficient of lateral earth pressure (dimensionless)

γ = unit weight of free-draining granular material, kN/m^3

h = depth below final grade, m

q = surcharge load, kPa, if present

C_p = compaction pressure, kPa (refer to clause 6.9.3 of CHBDC)

C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)

where ϕ = angle of internal friction of retained soil

δ = angle of friction between the soil and wall

Free-draining granular material should be used as backfill behind the wall. The following parameters are recommended for design:

Table 3 – Geotechnical Parameters for Granular Backfill

PARAMETERS	GRANULAR A OR GRANULAR B TYPE II	GRANULAR B TYPE I
Internal Friction Angle, ϕ (degrees)	35	32
Unit weight, γ (kN/m^3)	22.8	21.0
Coefficient of Active Earth Pressure, K_a	0.27	0.31
Coefficient of Earth Pressure At Rest, K_o	0.43	0.47
Coefficient of Passive Earth Pressure, K_p	3.69	3.25

The coefficient of earth pressure at-rest should be used for design of rigid and unyielding walls, the active earth pressure coefficient for unrestrained structures. The earth pressure coefficients should be reviewed if the slope of the backfill exceeds 10° to the horizontal. Alternatively, the material above the top of the wall could be treated as a surcharge load (q in the preceding equation).



The magnitude of the passive resistance is dependent on the actual lateral movement of the structure toward the retained soil. We refer to Figure C6.16 of the CHBDC for this computation. The subsoil / backfill should be considered as medium dense sand for the project.

4. CONSTRUCTION CONSIDERATIONS

4.1 Excavation

Excavation for construction of the retaining walls is expected to extend through the fill and native soils to depths of up to 4 m below existing grade. Excavation of these soils should be relatively straightforward.

The fill and typically loose to compact cohesionless soils are classified as Type 3 soils according to Occupational Health and Safety Act (Ontario Regulation 213/91) criteria. Temporary cut slopes in earth over the full depth of excavation should therefore be inclined at an angle of 45° to the horizontal. The need to excavate flatter side slopes if excessively soft/wet materials or concentrated seepage zones are encountered locally during construction should be considered. It is noted that very loose sandy layers revealed at the locations of boreholes RW-3, RW-4 and EB-3 are classified as Type 4 soils and, if cut into, require temporary slopes to be inclined at 3H:1V.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

4.2 Roadway Protection

It is anticipated that a suitable roadway protection scheme following OPSS.PROV 539 will be necessary between the new EBL and existing embankments to support the walls of excavation during construction.

Several alternative protection schemes such as sheet piling, sheeting supported by rakers or bracing, cantilever or anchored soldier piles and lagging may be considered. It is noted, however,



that a soldier pile and lagging scheme is not considered adequate where the excavation will extend through sandy soils, particularly below the water table due to potentially excessive loss of the retained soils during installation.

A road protection scheme designed for an OPSS.PROV 539 performance level 2 system is recommended to prevent excessive movement of the existing embankment. The contractor is responsible for the selection, preparation and performance of a detailed design for the road protection scheme.

4.3 Groundwater Control

The groundwater was at elevation 74.9 to 75.3. The water level in the Desjardins Canal was at elevation 75.0 on August 30, 2015. It is considered that seepage from soil fissures or surface water run-off that enters the excavation should be readily handled by conventional sump pumping techniques. It is worth noting that groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns, generally reflecting the water level in the adjacent Desjardins Canal.

5. BACKFILL AND DRAINAGE CONTROL

The drainage behind the RSS walls should be designed by the RSS supplier.

The backfill behind the cast-in-place concrete retaining walls should consist of suitable free draining granular materials such as Granular A or B containing less than 5% of fines. The backfill geometry should be in accordance with OPSD 3121.150. The backfill should be placed and compacted to at least 95% of the standard Proctor maximum dry density.

Backfilling adjacent to retaining walls should be carried out in conformance to OPSS.PROV 501. Operation of compaction equipment at the retaining structures should be restricted to limit the compaction pressure noted in clause 6.9.3 of the CHBDC. Refer to OPSS.PROV 501 for additional information in this regard.



All backfilling and compaction operations should be supervised on a full-time basis by geotechnical personnel to examine and approve backfill materials, evaluate placement operations and verify that the specified degree of compaction is achieved uniformly throughout the fill.

A subdrain system (OPSS 405) and weep holes (OPSD 3190.100) should be installed to minimise the build-up of hydrostatic pressure behind the cast-in-place concrete retaining walls. The subdrain tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-100 μm according to OPSS 1860) to prevent migration of fines into the system. The drainage pipes should be installed on a positive grade and lead to a frost-free outlet.

The earth fill slopes should be protected against surface erosion by sodding and suitable vegetation. Refer to OPSS 803 and OPSS 804 for time constraints and the type of seed and mulch required.

The upper 600 mm of backfill against the wall should consist of relatively impermeable local clayey material to mitigate stormwater infiltration.



6. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Project Manager and MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.



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GD/CN:gd-mi



TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 803	Construction Specification for Sodding
OPSS 804	Construction Specification for Seed and Cover
OPSS 1860	Material Specification for Geotextiles
OPSS.PROV 501	Construction Specification for Compacting
OPSS 405	Construction Specification for Pipe Subdrains
SP 599S22	Requirements for The Design, Supply and Construction of Retaining Soil Systems (RSS)
SP 599S23	Requirements for Materials, Quality Control and Quality Assurance Testing and Acceptance Criteria for Precast Concrete Facing Elements Including Panels
OPSD 3090.101	Foundation Frost Depth for Southern Ontario
OPSD 3120.100	Walls – Retaining Concrete Toe Wall
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls
OPSD 3190.100	Retaining Wall and Abutment Wall Drain Detail

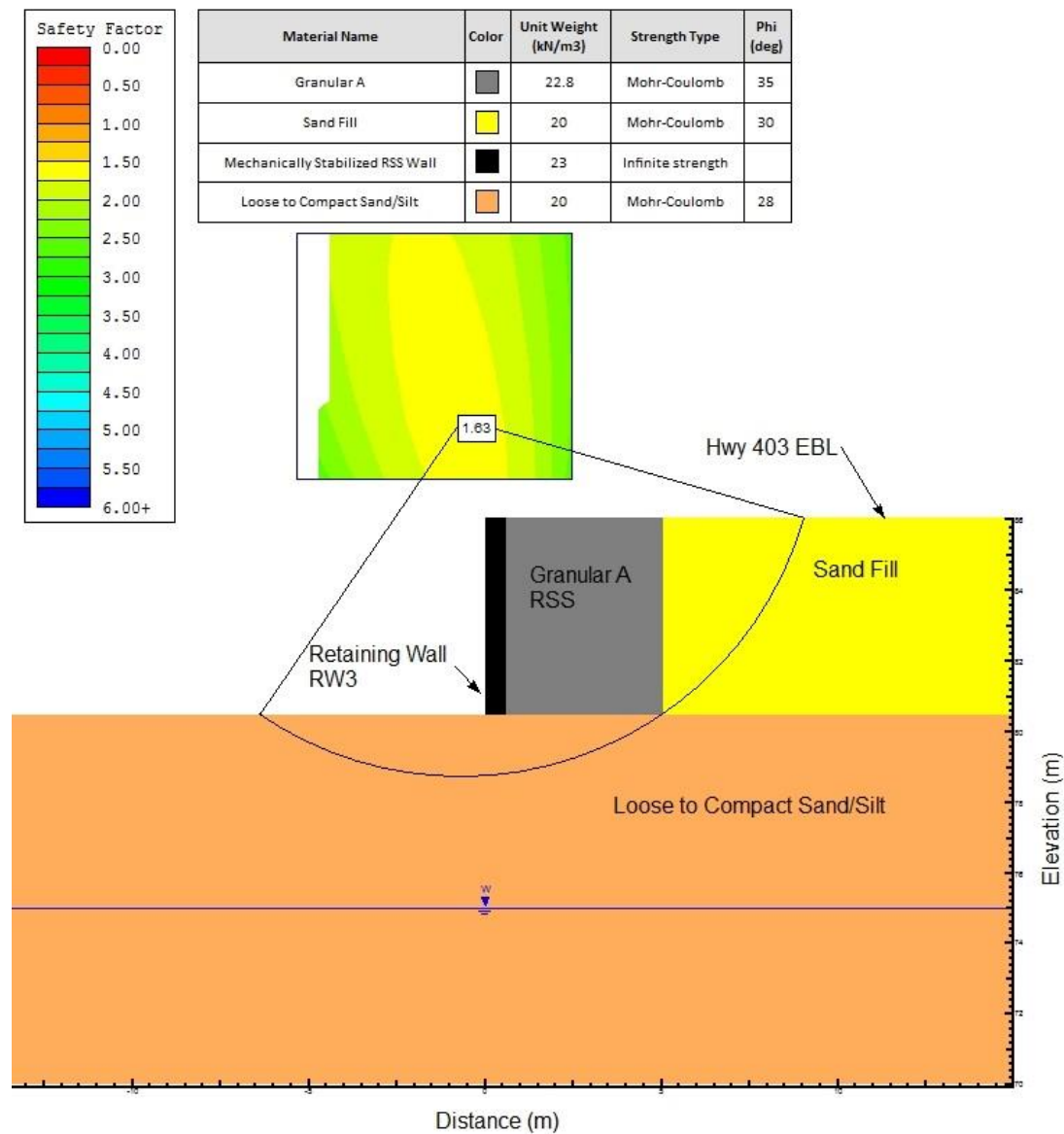


FIGURE 1: Stability Analysis – Retaining Wall RW3

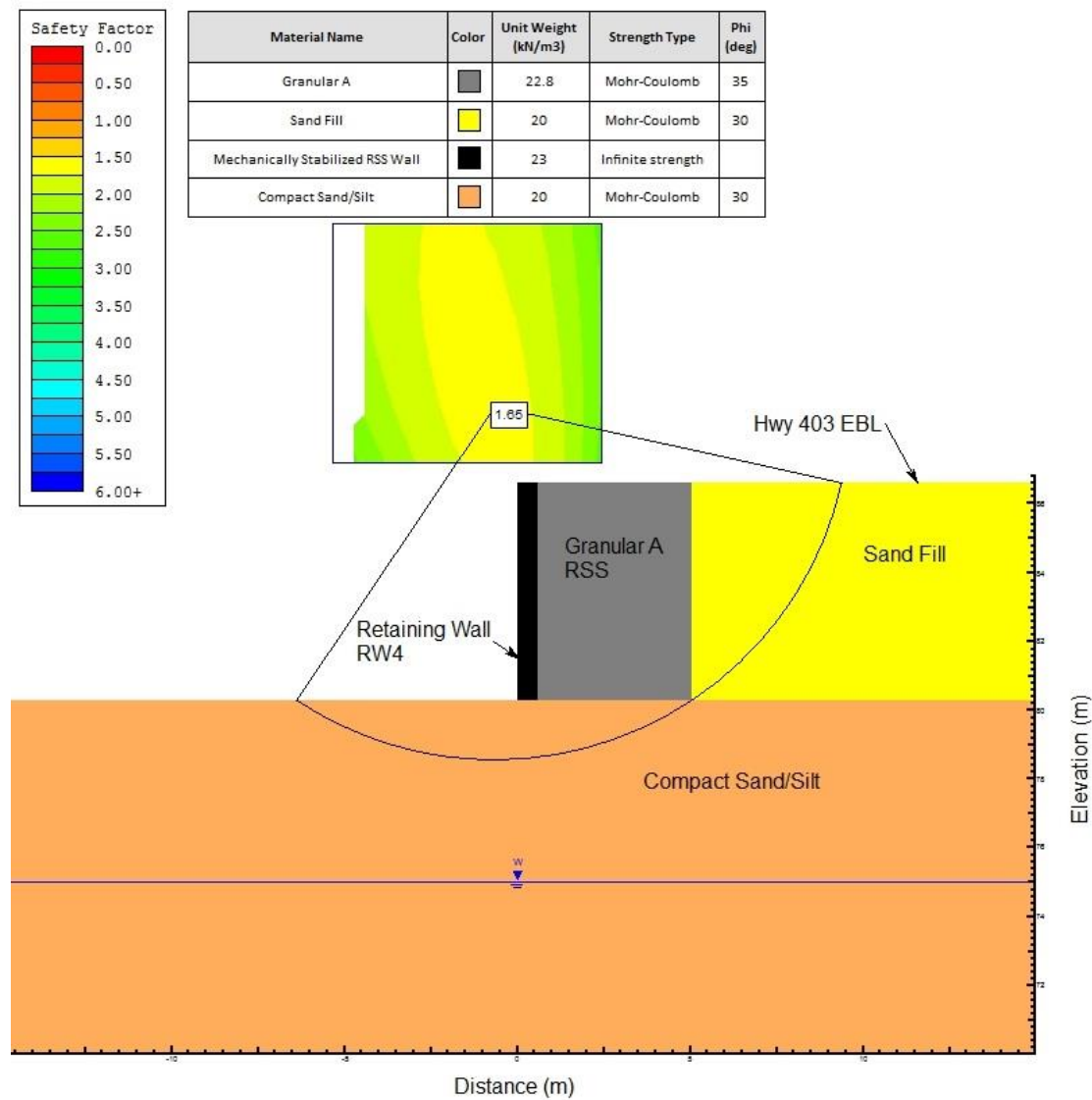


FIGURE 2: Stability Analysis – Retaining Wall RW4

